EXHIBIT 3

UNITED STATES DISTRICT COURT
DISTRICT OF MINNESOTA

In re: Bair Hugger Forced Air Warming Products Liability Litigation	MDL No. 2666 (JNE/FLN)
This Document Relates to: *Louis C. Gareis v. 3M Co., et. al.* 16-cv-4187	**EXPERT REPORT OF SAID ELGHOBASHI, PH.D.**

1. **Introduction and Preliminary Statement:** I previously outlined my opinions on general causation and my expert opinions regarding impact the Bair Hugger forced air warming device has on distributing 10 micron sized particles around the operating room, and onto both the surgical tables and the surgical field. I incorporate those opinions in their entirety into this report.

2. **Reserve the Right to Amend/Supplement:** It is my express understanding that case-specific discovery remains open regarding Mr. Gareis' case and that none of the treating physicians have been deposed yet, nor has third party discovery concerning the hospital in question been completed. Accordingly, I reserve the right to amend and/or supplement this report in the future upon receipt and review of additional records or other evidence.

3. All opinions expressed in both my general causation expert report and this case specific expert report are opinions I hold to a reasonable degree of scientific certainty.

S. Elghobashi

Said Elghobashi, Ph.D.
November 27, 2017

November 21, 2017- 12:11

Calculation of Velocity and Temperature of Heated Air Leaving the BH Blanket with Blower Model 505

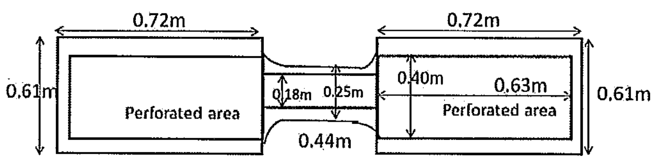
Said Elghobashi
Mechanical and Aerospace Engineering Department, University of California, Irvine

1 Calculation of velocity and temperature of heated air leaving the BH blanket with Blower Model 505

The objective of this report is to calculate the velocity and temperature of heated air as it leaves the BH blanket and enters the OR. In order to calculate the air temperature we need to calculate the heat transfer rate from the air to the patient's chest and arms. Since the heat transfer between the air and body occurs by forced convection, then we need to compute the velocity of the air as it moves between the BH blanket (with Blower Model 505) surface and the body.

1.1 Velocity of heated air leaving the BH blanket

Figure 1 shows the planar geometry of the BH blanket Model 522 before inflating it.



BH blanket model 522
[188cm x 61cm]

Figure 1: BH blanket geometry before inflation

In order to calculate the velocity of the air leaving the blanket we should consider the shape of the inflated blanket when it is connected to the BH blower as shown in Fig.2.

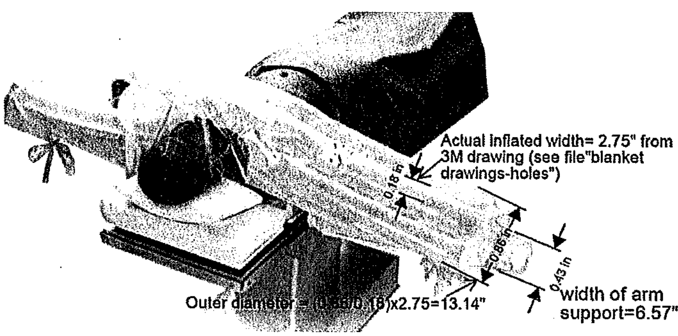


Figure 2: BH Inflated Blanket. The dimensions with the red arrows are for PDF scaling only.

Fig.3 shows a cross-section of the inflated blanket after being wrapped around the arm.
The diameter of the cylindrical surface facing the arm $=0.194m$ which when unwrapped flat would produce the width of the blanket ($= 0.61m$) as shown in Fig.1, according to $L = \pi D$.
The width of the heated-air gap between the arm and the blanket surface $= \frac{(0.194-0.127)}{2} = 0.0335m$.
The heated air issuing from the blanket holes (one thousand holes, each 1mm diameter) leaves the blanket across that gap on the right and left arms.

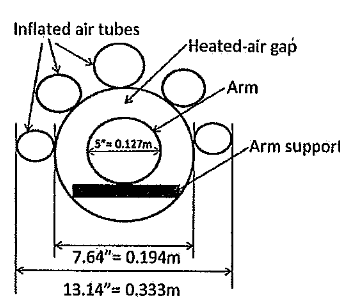


Figure 3: BH cross-section of inflated blanket

The total cross-sectional area of both the right and left gaps $= 0.0335 \times 0.61 \times 2 = 0.04087 m^2$.
Thus, **the velocity of air leaving the right and left arms=**

$$\frac{\text{Blower505 volumetric flow rate}}{\text{gap area}} = \frac{0.01416\,\mathrm{m^3/s}}{0.04087\,\mathrm{m^2}} = \mathbf{0.3465}\,\mathrm{m/s}$$

It should be noted that this is the velocity *before the air reaches the drape* that covers the blanket. The air will then leave the drape edges at a lower velocity as shown in Fig.4.

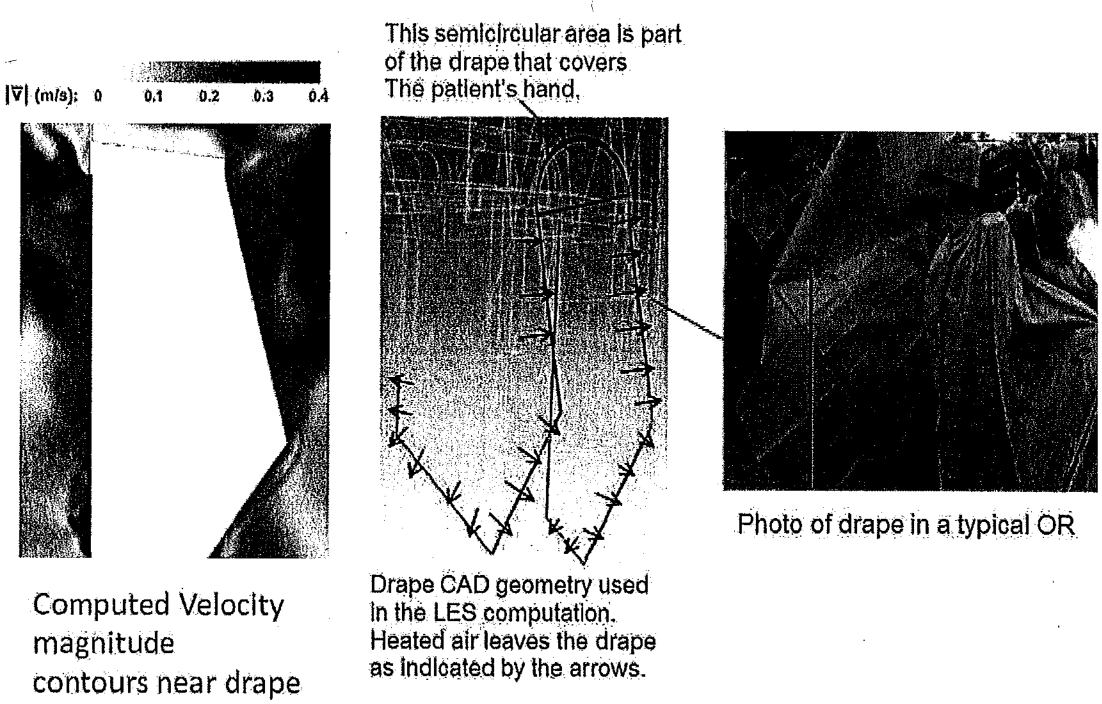


Figure 4: Drape geometry and heated air velocity near the drape.

1.2 Temperature of heated air leaving the BH blanket

In order to calculate the exit air temperature we apply the First Law of Thermodynamics to the control volume shown in Fig.5. For a steady-state condition we have:

$$\dot{m}_{in}\, h_{in} = \dot{m}_{exit}\, h_{exit} + \dot{q}_{body}\ , \tag{1}$$

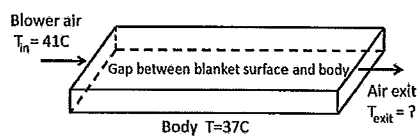


Figure 5: Schematic for heat transfer from air to body

where
$\dot{m}_{in}$= mass flow rate of blower air (kg/s)
$=$ air density $\times$ volumetric flow rate $= 1.127 \times 0.01416 = 0.01596\,\mathrm{kg/s}$,
$\dot{m}_{exit}$= $\dot{m}_{in}$= $\dot{m}$ = mass flow rate of air leaving the blanket $= 0.01596\,\mathrm{kg/s}$,
h_{in}= enthalpy of air from the blower (kJ/kg),
h_{exit}= enthalpy of air leaving the blanket (kJ/kg),
$\dot{q}_{body}$ = rate of convective heat transfer from the air to the body (kJ/s= KW).
Since $\dot{m}$ is constant, Eq.(1) can be recast as:

$$h_{in} = h_{exit} + \dot{q}_{body}/\dot{m}, \tag{2}$$

The inlet enthalpy, h_{in}, is obtained from Thermodynamics Tables of air (e.g. [2], page 660) at the temperature of 40.5C. The Table gives $h_{in} = 313.5\,\mathrm{kJ/kg}$. Our goal is to find h_{exit} since it will give us T_{exit} via Thermodynamics Tables of air. Thus, we must first calculate the heat transfer to the body, $\dot{q}_{body}$.
Since the heat transfer from the air to the body is by forced convection, we have

$$\dot{q}_{body} = h_c \times \text{Area of blanket surface} \times (\mathrm{T_{air}} - \mathrm{T_{body}})\ , \tag{3}$$

where h_c is the coefficient of convective heat transfer from air to body. This coefficient

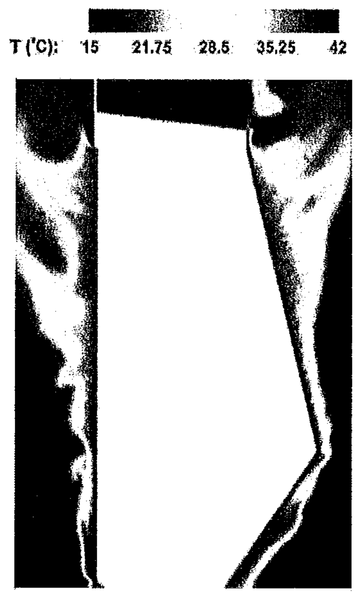


Figure 6: Heated air temperature near the drape.

depends on the air velocity that was calculated in the previous subsection as $0.3465\,m/s$. Reference [1] provides experimental data of the heat transfer coefficient to the chest of a human as a function of the air velocity according to: $h_c = 9.1 \times V^{0.59}$. For a velocity $V = 0.3465\,m/s$, $h_c = 4.8689\,W/m^2K$.
The temperature difference is $T_{air} - T_{body} = (40.5 + 273.15) - (37 + 273.15) = 3.5K$.
The area of the blanket surface delivering the heated air is marked by the red contours in Fig.1:
Area$=2(0.63 \times 0.4) + (0.44 \times 0.18) = 0.5832\mathrm{m}^2$. Substitution in Eq.(3) gives:

$$\dot{q}_{body} = 4.8689\,\mathrm{W/m^2K} \times 0.5832\mathrm{m}^2 \times 3.5\mathrm{K} = 9.939\mathrm{W} \tag{4}$$

Substitution in Eq.(2) gives:

$$313.5\,\mathrm{kJ/kg} = \mathrm{h_{exit}} + 9.939\mathrm{W}/(1000 \times 0.01596\mathrm{kg/s}), \tag{5}$$

which results in $h_{exit} = 313.5\,\mathrm{kJ/kg} - 0.6227\,\mathrm{kJ/kg} = 312.9\,\mathrm{kJ/kg}$.
Using this value of h_{exit}, and the Tables in [2], page 660, gives $\mathbf{T_{exit} = 39.73\,C}$.

It should be noted that as the body temperature rises above 37C due to the continuous (e.g. for one hour) heating by air, the value of $\dot{q}_{body}$ will be reduced, and the exit air temperature T_{exit} will approach 40.C asymptotically, as shown in Fig.6 which will be updated after the new simulation is completed.

1.3 Approximate estimate of the time taken by squames to reach the operating table when using the BH blower model 505

This approximate estimate is based on the first law of thermodynamics.
• Reducing the flow rate of the BH blower from 44.5 cfm ($= 0.021m^3/s$ for the 750 model) to 30 cfm ($= 0.01416m^3/s$ for the 505 model), and
• reducing the air temperature leaving the perforated side of the BH blanket from 41C to 40.5 C, then
• based on my education, training, and experience, along with the LES CFD I did with respect to the BH 750, it is my professional opinion that while all other conditions in the OR are kept the same, it is expected that the turbulent heated air plume and the dispersion of the squames observed in the case of the model 750 will be reproduced for the model 505 *but* after a longer time. It is my professional opinion that this time will be between 25 seconds and 60 seconds. However, the exact time can only be calculated with precision by performing the simulation with our LES computer program.

References

[1] R.J. de Dear, E. Arens, Z. Hui, and M. Oguro. Convective and radiative heat transfer coefficients for individual human body segments. *Int J Biometeorol*, 40:141–156, 1997.

[2] R.E. Sonntag, C. Borgnakke, and G.J. Van Wylen. *Fundamentals of Thermodynamics, 6th Ed.* Wiley, New York, 2002.